NEW TECHNIQUES FOR IMPLEMENTING ONLINE VIRTUAL LABORATORIES

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Abstract:

This work describes a practical method for the design and development of online virtual laboratories using low costs electronics and software applications. Such virtual labs are needed in any education institution that desires to offer good quality teaching services for their students and can be integrated inside e-learning platforms. A practical example is included in this research and makes use of communication technologies together with microcontroller performance, possible due to high availability of many forms of Internet-enabled modules, which generated in the last years in the so-called "Internet of Things" (IoT) – a global network of sensors and smart devices communicating with each other. These smart platforms capture data from different sensors and transmit it over Internet for further processing or interpretation, and graphical results can be embedded into a Moodle course, as a laboratory teaching resource, thus expanding the e-learning services. The case study presented is the author's experimentation in laboratory space and can be easily replicated for further research.

Keywords: education, virtual laboratory, e-learning, online services

JEL Codes: L63, L86

1. Introduction

Along with the development of Internet communication in the last decade, many education institutions started new research in the design and development of online virtual laboratories for technical fields like Automatics or Electronics. To achieve this goal, universities have co-worked with specialized developers like National Instruments and purchased proprietary high cost solutions for the development of online virtual labs needed in e-learning education. Examples of works using such implementations include:

- Design of online v-labs for automation control engineering education with NI LabVIEW (Stefanovic et al., 2011);
- Robotics virtual labs with remote access using EJS[6], MATLAB and LabVIEW (Chaos et al., 2013).

In addition to proprietary applications like Matlab or LabVIEW educational institutions can now use free or open source tools for design and implementation of virtual labs.

Current state-of-the-art

In recent years, organizations used to offer products and complete services for modern education, including virtual laboratories for more engineering technical fields. Purchase costs of a complete integrated system for a number of laboratory experiments consist of tens of thousands of Euros; from here, the major disadvantage can be seen as the high price of acquisition. Even in our country there are some providers who sell such solutions to public high schools and universities, but only those who can afford to purchase them.

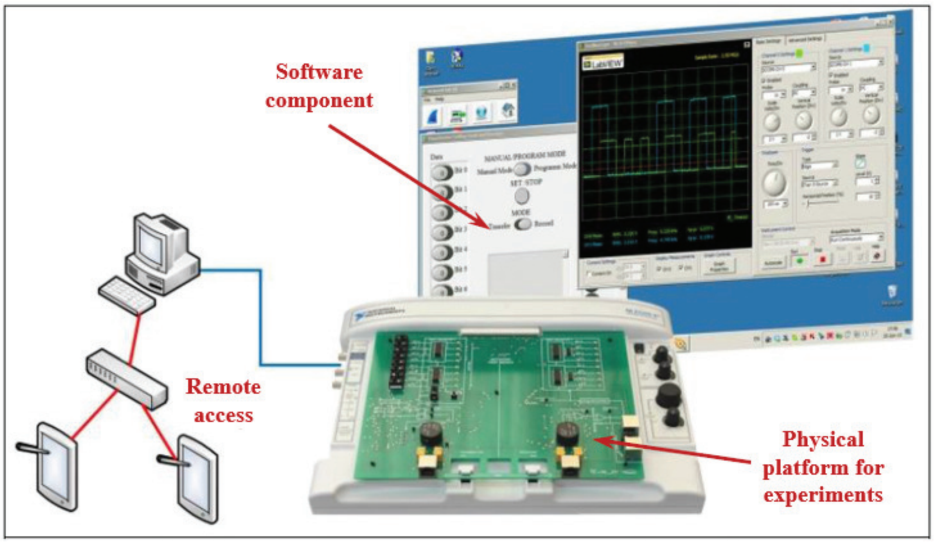

Fig. 1 – Virtual laboratory, a National Instruments product

Figure 1 presents an example of such product provided by National Instruments organization, who can also offer less costly solutions for students and academic use, though with limited functionality.

Other institutions can not afford these costly products, and are forced to find alternative solutions, in order to remain competitive in academia and have the ability and capacity to provide a modern teaching process.

[6] Easy Java/JavaScript Simulations - http://www.um.es/fem/EjsWiki/pmwiki.php .

The following is a practical research with a case study, using e-learning platform as a basis for integrating virtual labs inside courses.

2. Case study: A virtual lab inside Moodle e-learning platform

For the demonstration, an electronic platform is designed and implemented to be equipped with sensors and actuators, the platform being monitored and controlled remotely through an HTML page inside a Moodle course. The goal is to catch and display data from sensors and also to interact with the physical platform, but from distance, via a web page delivered by the system, in our case to generate a servo motor movement.

The hardware

The chosen components of the hardware needed for the lab include:

- ARDUINO NANO development platform (http://www.arduino.cc), with 8-bit AVR Atmel ATmega328P microcontroller;
- Arduino ETHERNET SHIELD (WIZnet W5100), for network connectivity;
- HC-SR04 ultrasonic sensor, used for motion detection;
- LM35 temperature sensor;
- One servo-motor, for movement generation;
- One RGB led;
- One breadboard for wiring and testing purposes.

This platform can be used for developing monitoring and control applications with remote access, such as: reading and transmitting sensor data (temperature, motion), controlling different actuators to move things, etc.

Figure 2 shows the electronic scheme produced with the Fritzing electronic design software, all the components and connections being made with respect to wiring methodology and electronic rules.

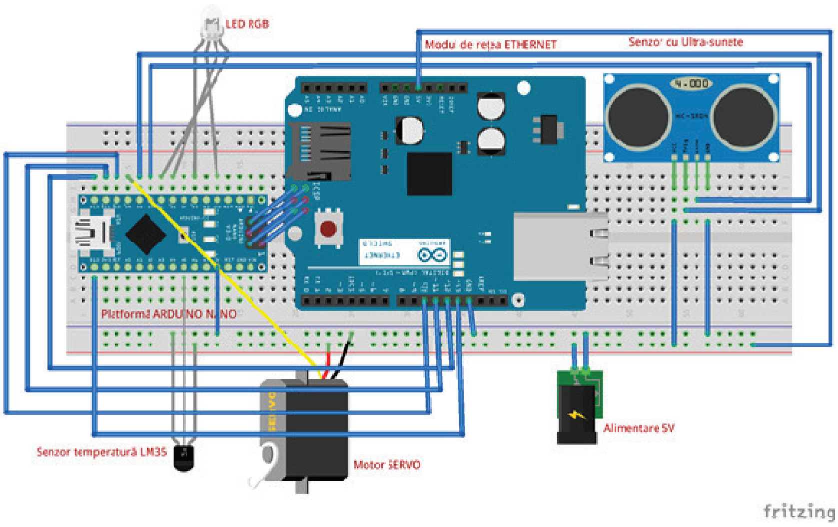

Fig. 2 – Electronic scheme designed with Fritzing software

The Ethernet WIZnet W5100 module is connected and programmed by the Arduino Nano board and permits remote operations for the platform.

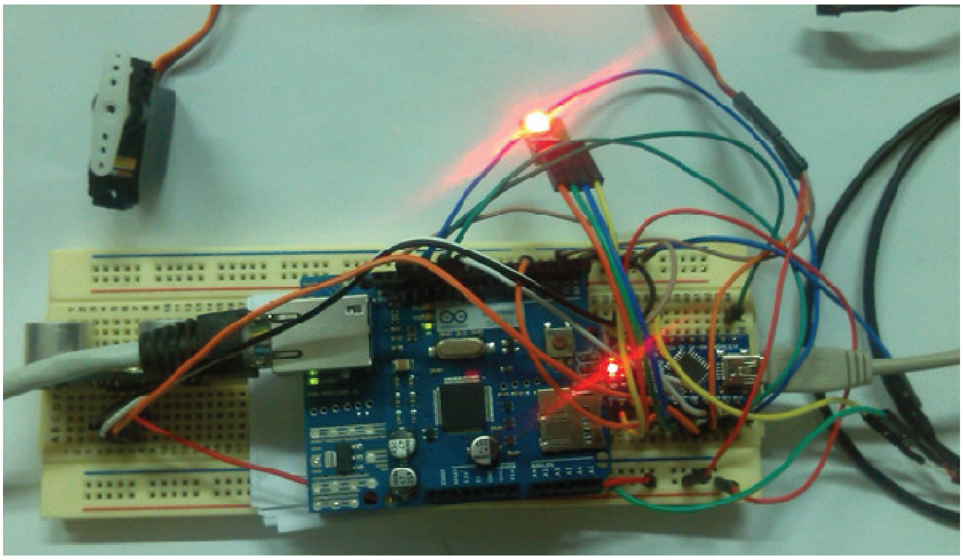

Fig. 3 – View of the real implementation of the platform

A view of the real platform is presented in Figure 3, in which we can observe an active state of the application. The breadboard is widely used for testing purposes, due to the ease of connecting various components to it.

The software

Using the Arduino IDE a software program is developed that, after compilation and execution, provides an HTML page with information about sensors values, and the possibility to act buttons for lighting up an RGB led and moving a servo motor. The HTML is coded inside a C program and the Ethernet module delivers it through the TCP/IP protocol. A part of the C code is as follows:

```
#include <SPI.h>
#include <Ethernet.h> // neccessary libraries
#include <Servo.h>
Servo myservo;
byte mac[] = { 0x90, 0xA2, 0xDA, 0x0F, 0x64, 0xD2 };
// MAC address of the Ethernet module
byte ip[] = { 131, 159, 35, 49 };
// IP address of the module
EthernetServer server(80);
String readString; // variabila pentru urmarirea stringurilor
int ledPin = 3; // pin for RGB led
// HCSR04 motion detection variables, 7 and 8 digital pins
int trig = 7;
int echo =  8;
unsigned long pulsetime = 0;
int distFront;
int distLimit = 20;
// temperature sensor variables
float tempC;
int reading;
int tempPin = 5;
void setup() {
pinMode(ledPin, OUTPUT);
Ethernet.begin(mac, ip);  // network initialize
myservo.attach(9);  // servo initialization
myservo.write(0);
// HCSR04 pin settings
pinMode(trig, OUTPUT);
pinMode(echo, INPUT);
analogReference(INTERNAL);
}
void loop() {
EthernetClient client = server.available();
if (client) {
while (client.connected()) {
if (client.available()) {      // Pornirea server-ului
char c = client.read();
if (readString.length() < 100) {
readString += c;
}
if (c == '\n') {
Serial.println(readString);
// HTML code programmed in microcontroller
client.println("HTTP/1.1 200 OK");
client.println("<hmtl>");
client.println("<head>");
client.println("<title>Proiect ARDUINO, ETHERNET,
Monitorizare si Control</title>");
```

```
client.println("</head>");
client.println("<body bgcolor=PaleGoldenRod>");
client.println("<font color=#444444>");
client.println("<meta http-equiv=\"refresh\" content=\"4\">"); // HTML page refresh rate
client.println("<center>");
// section for sensor data monitoring (motion, temperature)
client.println("<b>");
client.println("Aplicatie pentru monitorizarea si controlul de la distanta a unor sisteme electronico-mecanice!");
client.println("</br>");
client.println("MONITORIZARE SI CONTROL");
… … …
… … …
```

The Arduino IDE provides a comfortable way to write simple C-like code and there are dozens of applications on the web available to users everywhere. The simplicity of programming has led to earning a worldwide reputation of the Arduino, both as a software developer and provider of open source electronic platforms.

The Moodle course

The provided HTML page can be easily embedded inside a Moodle course, in a laboratory section. The web page is served by the Arduino microcontroller board through the Ethernet module, and then is integrated in Moodle using the IP address and the URL. Thus, students have opportunities to study processes such as automation directly from an e-learning platform, including the control of physical elements. Figure 4 shows this aspect, the virtual lab being a teaching resource inside a Moodle course.

Fig. 4 – A virtual lab presented as a Moodle course activity

The major advantage of this approach is the availability of distance educational services. Students need no longer to be physical present in the laboratory room, if experiments can be access remotely via e-learning courses.

Through the integrated web page in the Moodle course, we can monitor LM35 temperature sensor and motion detection in front of HC-SR04 ultrasonic sensor. We can also click buttons LED1-ON and LED1-OFF to light on and off the RGB led, or buttons Servo-0, Servo-45 and Servo-90 to have motion control of servo at angles of 0, 45 or 90 degrees, all these operations being performed remotely.

Another experiment performed uses latest communication technology with both, hardware and software. For hardware it is used a well-known module, the ESP8266 Wi-Fi wireless device, which has support for 802.11b/g/n standard connectivity, and for the software it is chosen a modern web service, ThingSpeak.com, with which devices can send and receive data over Internet.

Figures 5 and 6 present the electronic system and the values of the temperature sensor, received by the ThingSpeak web service and represented graphically. Then the graphic can be also embedded inside Moodle platform.

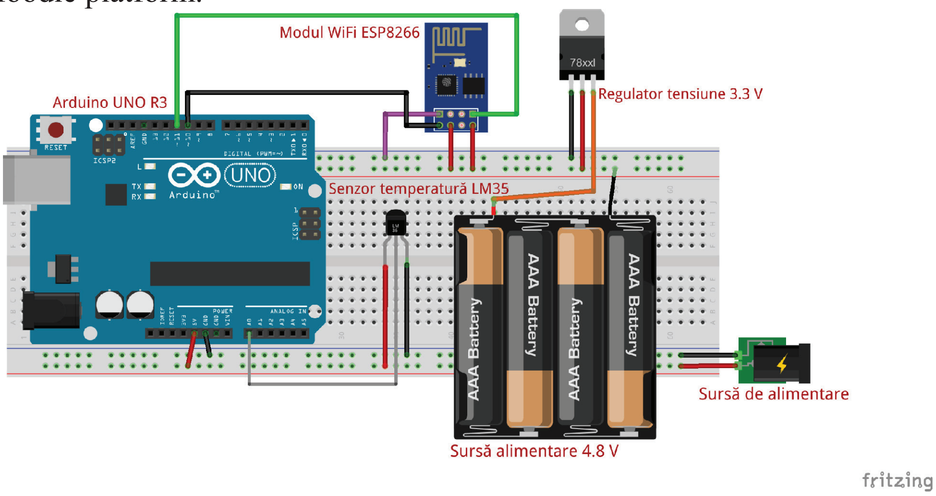

Fig. 5 – Electronic platform designed for testing the ThingSpeak web service

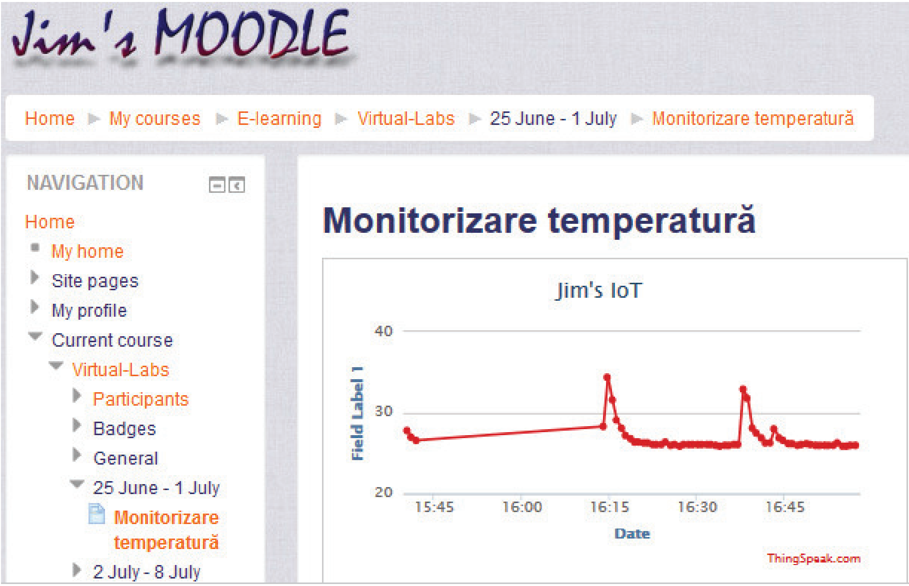

Fig. 6 – Temperature monitoring graphic generated by ThingSpeak.com and integrated inside a Moodle course

3. Conclusions

This paper has presented a modern and financially advantageous method for implementing online virtual labs for engineering fields. The approach is proved to be a satisfactory alternative to expensive products and services offered by companies like National Instruments and others. It was considered the benefits of modern electronics, which are more and more accessible, both as price and availability. The study had also practical experimentation, through the development of electronic platforms with sensors and actuators, which can be accessed remotely through a web page integrated into a Moodle e-learning course. With the expansion of the Internet of Things, devices can now send and receive data over Internet, and web services like ThingSpeak, mentioned in the paper, can further process data for better results.

In conclusion, online virtual labs are an increasing requirement for any academic and scientific institution, including in Romania, in order to be competitive and offer a modern educational process.

4. References

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Acknowledgements

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